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ORIGINAL PAPER

Implications of multipurpose tree leaf application on wheat productivity in dry tropics

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Abstract: Leaves of multipurpose tree species (those providing more than one function or product of human use) can serve as sources of fertilizer for nutrient supply, especially nitrogen (N). In this study chopped leaves of tropical tree species (5 N-fixing species, 5 non-N-fixing species and combinations of 5 N-fixing with a non-N-fixing species) were incorporated in soil to evaluate its effects on wheat biological productivity (including grain yield, G_{YIELD}) under dryland conditions. High quality leaves of N-fixing tree species (e.g. *Dalbergia sissoo*, *Cassia fistula* and *Prosopis cineraria*) had lower carbon/nitrogen (C/N), lignin/nitrogen (L_{IG}/N), polyphenol/nitrogen (P_{PL}/N) and lignin+polyphenol /nitrogen ($L_{IG}+P_{PL}/N$) ratios than low quality leaves of non-N-fixing species. Combination treatments had intermediate values of different parameters. Application of high quality leaves caused greater increases in wheat productivity and yield than other species. By the application of leaves of N-fixing trees, on average, wheat yield increased 160% relative to the control (no addition of leaves), and when combined with non-N-fixing *Terminalia chebula* leaves the yield increased 108%. Mean total net productivity (T_{NP}) with N-fixing species treatments, exceeded mean T_{NP} with non-N-fixing species and combination treatments by 50% and 28%, respectively. Multivariate regressions indicated that nitrogen (N) concentration in leaves (main nutrient), interacting with lignin (L_{IG}) and polyphenol (P_{PL}) concentrations, explained 79%–86% of variability in productivity parameters and yield. Strong correlation between $L_{IG}+P_{PL}/N$ ratio of leaves with G_{YIELD} of wheat crop suggests that the ratio can be used as a reliable index for mass screening of multipurpose tree species for use as soil amendments especially in dryland agriculture. Direct application of high quality N-fixing tree species leaves (especially *D. sissoo*, *C fistula* and *P. cineraria)*, an uncommon practice in dry tropics in India, may serve as a short-term option for rapid enhancement of wheat productivity and soil fertility.

Keywords: multipurpose tree leaves; chemical quality index; grain yield, N-fixing species; non-N fixing species; Dryland agriculture

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Introduction

The search for low-input and energy efficient agricultural systems is now a priority of researchers and policy makers, especially in the tropics, where subsistence agriculture is widespread and the use of inorganic fertilizer is limited. The search is difficult in developing countries of South Asia including India where land degradation has become a major problem (Semwal et al. 2003). The role of multipurpose tree species (those providing more than one significant function or product, such as shade, timber, fuelwood, fodder, food or medicine) in support of agriculture has been recognized. The declining trend of organic matter content in tropical cultivated soils and scarcity of traditional organic inputs (e.g. farmyard manure) have necessitated looking for alternatives such as the application of leaves of multipurpose trees to farmlands to add both fertilizer and organic matter. The importance of N-fixing trees for soil management has been emphasized as a source of fertilizer (Chirwa et al. 2003).

Sustainable agriculture must focus on biological soil fertility management, relying on a careful synchronization of crop nutrient needs with the availability of those nutrients in the soil (Myers et al. 1994; Sarrantonio 2003; Kundu et al. 2007). While many studies have reported on leaf/litter decomposition and nutrient release of tropical agroforestry/multipurpose tree species (Byard et al. 1996; Mwiinga et al. 1994; Palm et al. 1997), fewer studies have evaluated the impact of tree leaves on the production/yield of major cereal crops. Prunings from several multipurpose tree species incorporated in soil significantly increased dry matter and yield in maize (Tian et al. 1993), and showed higher nitrogen recovery in the crop (Mafongoya et al. 1996). Amongst the nine agro-forestry tree species, whose leaf pruning

was applied to wheat, most species increased grain yield and few had adverse effects (Anthofer et al. 1998). Walnut and pine leaves also significantly increased wheat yield (Akkaya et al. 2006).

The chemical quality of tree leaves used as soil amendments determines their decomposition rate and subsequent nutrient availability in soil, which, in turn, affects the productivity of crops. The rate of nitrogen mineralization from decomposing plant residues is affected by initial concentrations of nitrogen (N), lignin (L_{IG}) and soluble polyphenol (P_{PL}) but published results show differences with respect to properties which correlated best with nitrogen release (Costantinides and Fownes 1994). High N, low L_{IG} and low P_{PL} content are typical of high quality plant residues which generally decompose rapidly (Haynes 1986). Handayanto et al. (1994) showed that variation in nitrogen release patterns among different plant residues were strongly related to differences in the lignin+polyphenol/N (L_{IG}+P_{PL}/N) ratio and protein-binding capacity of polyphenols. Cumulative nitrogen release from leaves, twigs and roots of *Gliricidia* could be predicted with the L_{IG}+P_{PL}/N ratio of the initial substrate; at ratios greater than 10, nitrogen release was independent of this ratio (Lehman et al. 1995). Comparing ten species used as green manure, Silva et al. (2008) found that L_{IG}/N and L_{IG}+P_{PL}/N ratios showed high correlation with decomposition rate and nitrogen release. Knowledge of chemical composition of tree leaves, especially N, L_{IG} and P_{PL} content can help in assessing their probable effect on crop productivity.

In India about 68% of farmlands are not irrigated and yield considerably less than irrigated farmlands (32% of arable land); hence, yield improvement in dryland agriculture is a priority of programmes aimed at food security. Since the use of chemical fertilizers is limited in drought prone drylands, tropical multipurpose tree species, especially the N-fixing species, whose leaves can be used as soil amendments, hold promise as a source of nutrients and organic matter. We undertook this study on common multipurpose tree species in the Indian dry tropics, both N-fixing and non-N-fixing, with the following objectives: (1) To evaluate the chemical quality of tree leaves; (2) To assess the effect of different tree leaves used as soil amendment on the biological productivity including grain yield of wheat; (3) To examine the relationships between leaf chemical quality and wheat productivity. Our goal for this study was to help guide the formulation of organic fertilization methodology using tree leaves without composting or any other pretreatment, an approach hitherto unused by farmers in the region. Generally, farmers use inorganic fertilizers and/or green manure or composted materials when available.

Materials and methods

Study site

This study was carried out in the cultivated field of the Botanical Garden of Department of Botany, Banaras Hindu University (25° 18′ N and 83°1′ E, 76 m, above sea level). The region has a tropical sub-humid seasonal climate with a warm-rainy season (July-September), a cool-dry winter (November-February), and a hot-dry summer (April-June); October and March are transitional months between seasons. The soil of the study site belongs to the order Inceptisols, sub-order orchrepts, sub-group udic ustocrepts (Srivastava and Singh 2002). The topsoil is loamy, neutral in reaction with 0.79% organic C and 0.08% total N.

Experiments were designed using leaves of ten tree species as soil amendments. Among the test species, five were N-fixing and five non-N-fixing. The N-fixing species were: *Dalbergia sissoo* Roxb. (Papilionaceae), *Bauhinia variegata* Linn. (Caesalpiniaceae), *Cassia fistula* L. (Caesalpiniaceae), *Prosopis cineraria* (Linn.) Druce (Mimosaceae) and *Casuarina equisetifolia* J.R.Forst & G. Forst (Casurinaceae). The non-N-fixing species were: *Sapindus emarginatus* Vahl (Sapindaceae), *Terminalia chebula* Retz. (Combretaceae), *Eucalyptus globulus* Labill. (Myrtaceae), *Madhuca indica* Gmel. (Sapotaceae) and *Holarrhena antidysenterica* (Roth) A. DC (Apocynaceae). Fresh leaves of these species were collected in November 2003, air dried in the laboratory 20–25°C), and cut into small (2 cm) pieces. Small pieces of leaves were applied directly on the soil without composting.

Chemical analysis

Air-dried tree leaves were milled and passed through 1 mm mesh screen and the initial chemical composition was determined in triplicate. Carbon content of the leaves was determined by the ignition method (McBrayer and Cromack 1980). Nitrogen content was estimated by the microkjeldahl method (Jackson 1973). Lignin content (Klason lignin) was measured using the method described by Effland (1977), and extractable polyphenols were quantified by the Folin-Denis method (Anderson and Ingram 1993). Carbon (C), nitrogen (N), lignin (L_{IG}) and polyphenol (P_{PL}) content yielded the following chemical ratios: carbon:nitrogen (C/N), lignin:nitrogen (L_{IG}/N), polyphenol:nitrogen (P_{PL}/N), lignin+polyphenol:nitrogen (L_{IG}+P_{PL}/N).

Experimental set up

The test crop, wheat (*Triticum aestivum*, var. HUW 533), was grown in field soil. The upper soil layer (0–10 cm) was collected from the cultivated field, crushed thoroughly to remove root fragments, and sieved through 2 mm mesh. The sieved soil was thoroughly mixed and placed in earthen pots (each 30 cm diameter, 25 cm height). Chopped leaves of the ten tree species and a combination series of the five N-fixing species each with the non-N-fixing *Terminalia chebula* were mixed well in the top 0-5 cm of soil. In total, there were 15 treatments (10 tree species plus 5 N-fixing species each combined with a non-N-fixing species) along with a control (no leaf addition). Single species leaves were applied at 280 $g \cdot m^{-2}$, and combined leaves at 140 $g \cdot m^{-2}$ each. For each of the 15 treatments there were 10 replicate pots.

Wheat seeds (5 per pot) were sown in December 2003 and the crop was harvested in April 2004. Pots were watered from time

to time during the growing season of the crop. Water content was maintained at about 2/3 of field capacity. All pots were placed in an experimental area, which was covered with 3-cm mesh size nylon net at the top (2.5 m height) and at the sides to exclude litter blown from external sources and prevent bird herbivory. The pots were randomly arranged in treatment blocks, which were spatially rotated every ten days. Periodically, three pots per treatment were removed for soil and plant sampling.

The crop biomass was estimated at seedling, grain-forming and maturity stages (40, 80 and 120 days after wheat sowing) by the harvest method (maturity stage data presented herein). Soil cores with wheat plants were carefully removed from the pots and the roots were washed with a fine jet of water over a three-sieve assembly (2 mm, 0.5 mm and 0.2-mm mesh, from top to bottom). The retrieved plant biomass was separated into shoot and root components. Further, the fraction of shoot representing grain yield was separated. All separated plant biomass components were oven dried at 80°C and weighed. The weight of shoot and root represented aboveground net productivity (A_{NP}) and belowground net productivity (B_{NP}), respectively, for the 120-day cropping period. The sum of A_{NP} and B_{NP} was the total net productivity (T_{NP}). T_{NP}, A_{NP}, B_{NP} and G_{YIELD} for the cropping period were expressed on a land area basis (g·m^{-2}).

Data analysis

Mean and standard error were computed for leaf chemical quality indices and wheat productivity parameters for each species and for the three groups (N-fixing, non-N-fixing and combination). One-way ANOVA was performed for all parameters to separately compute the Least Significant Difference (L_{SD}) at 5% level of significance for comparing the means of: (a) different species (15), and (b) species groups (3). Bivariate correlation and regression computations were made relating different wheat productivity parameters and leaf quality indices. Multiple regression analysis by the Enter method was done to assess interaction effects of the chemical quality indices of tree leaves on wheat productivity parameters. All computations were made using SPSS/PC+ software.

Results

Chemical composition of tree leaves

N-fixing and non-N-fixing tree species differed in chemical composition (Table 1). N-fixing species showed higher N concentration (2.4 ±0.1%) but lower lignin and polyphenol concentrations than non-N-fixing species. Leaves of N-fixing species showed lower chemical quality indices: *C/N* is 19.5±0.99, L_{IG}/N is 5.7±0.86, P_{PL}/N is 1.6±0.1 and $L_{IG}+P_{PL}/N$ is 7.4±0.88. Non-N-fixing species, on the other hand, showed distinctly higher indices: *C/N* is 26.8±1.2, L_{IG}/N is 9.8±0.93, P_{PL}/N is 5.3±0.69 and $L_{IG}+P_{PL}/N$ is 15.0±1.33. Combinations of low nitrogen containing *T. chebula* leaves with N-fixing leaves yielded intermediate values of these indices.

Table 1. Leaf chemical quality indices of tree species. L_{SD} (p<0.05) compares mean between species and between treatment groups in columns

Tree species	$N_{\%}$	Ratio of *C/N*	Ratio of L_{IG}/N	Ratio of P_{PL}/N	Ratio of $L_{IG}+P_{PL}/N$
N-fixing species					
Bauhinia variegata	2.2	20.6	8.3	1.9	10.2
Casuarina equisetifolia	1.7	26.1	10.7	1.4	12.1
Cassia fistula	2.5	18.6	3.1	1.8	4.6
Dalbergia sissoo	2.6	15.8	2.6	1.0	3.6
Prosopis cineraria	2.8	16.4	4.0	2.0	5.9
Mean± SE	2.4±0.10	19.5±0.99	5.7±0.86	1.6±0.10	7.4±0.88
Non-N-fixing species					
Eucalyptus globulus	1.9	25.2	14.1	5.1	19.2
Holarrhena antidysentrica	1.9	23.6	5.8	4.6	10.4
Madhuca indica	1.3	35.7	13.3	9.2	22.5
Sapindus emarginatus	1.7	24.2	9.2	1.2	10.4
Terminalia chebula	1.9	25.2	6.3	6.2	12.5
Mean± SE	1.7±0.06	26.8±1.20	9.8±0.93	5.3±0.69	15.0±1.33
Combined species					
B. variegata + T. chebula	2.0	22.8	7.4	3.9	11.3
C. equisetifolia + T. chebula	1.8	25.6	8.4	3.9	12.3
C. fistula + T. chebula	2.2	21.4	4.4	3.7	8.1
D. sissoo + T. chebula	2.0	21.5	4.5	3.5	7.9
P. cineraria + T. chebula	2.3	19.9	4.8	3.7	8.5
Mean± SE	2.1±0.05	22.2±0.52	5.9±0.45	3.7±0.05	9.64±0.49
L_{SD} (between species)	0.03	0.47	0.72	0.34	0.77
L_{SD} (between treatment groups)					
N-fixing and non-N-fixing species	0.04	0.40	0.85	0.38	0.89
N-fixing and Combination species	0.04	0.34	0.53	0.22	0.61
Non-N-fixing and Combination species	0.02	0.23	0.77	0.38	0.80

Population structure and regeneration status of tree species
Wheat productivity and yield

In different treatments the T_{NP} of wheat ranged widely between 550 and 1310 g·m^{-2} (cf. 488 g·m^{-2} in control) (Table 2). The A_{NP} and B_{NP} in different treatments ranged from 444–1064 g·m^{-2} (cf. 387 in the control) and 106–245 g·m^{-2} (cf. 101 in the control), respectively. In treatments with N-fixing species, mean A_{NP}, B_{NP} and T_{NP} increased 113%, 103% and 112%, respectively, over the control. The corresponding increases in treatments with non-N-fixing species were 41%, 39% and 41%, respectively. Combination treatments showed 66%, 64% and 65% increases, respectively, in A_{NP}, B_{NP} and T_{NP}. Among the N-fixing species, application of *D. sissoo* and *C. fistula* leaves showed substantially higher wheat productivity than other species. In combination treatments, however, *D. sissoo*, *C. fistula* and *P. cineraria* application showed similar levels of productivity. On average, T_{NP} in the N-fixing species treatments exceeded T_{NP} in the non-N-fixing species and the combination treatments by 50% and 28%, respectively.

Table 2. Effect of tree leaf treatments on aboveground net productivity (A_{NP}, g·m^{-2}), belowground net productivity (B_{NP}, g·m^{-2}), total net productivity (T_{NP}, g·m^{-2}) and grain yield (G_{YIELD}, g·m^{-2}) of wheat.

Tree species	A_{NP}	B_{NP}	T_{NP}	G_{YIELD}
N-fixing-species				
Bauhinia variegata	657	187	844	153
Casuarina equisetifolia	622	173	795	127
Cassia fistula	991	226	1217	216
Dalbergia sissoo	1064	245	1310	232
Prosopis cineraria	807	200	1008	199
Mean± SE	828±48	206±7	1035±55	185±11
Non-N-fixing-species				
Eucalyptus globulus	470	110	579	93
Holarrhena antidysentrica	585	166	751	124
Madhuca indica	444	106	550	85
Sapindus emarginatus	710	197	907	172
Terminalia chebula	530	127	657	95
Mean± SE	548±26	141±9	689±35	114±9
Combined species				
B. variegata + *T. chebula*	540	144	684	110
C. equisetifolia + *T. chebula*	586	137	722	106
C. fistula + *T. chebula*	701	180	881	172
D. sissoo + *T. chebula*	682	190	872	188
P. cineraria + *T. chebula*	705	180	886	166
Mean± SE	643±20	166±6	809±25	148±9
Control	387	101	488	71
L_{SD} (between species)	68	9	71	8
L_{SD} (between treatment groups)				
N-fixing and non-N-fixing species	71	11	72	12
N-fixing and Combination species	80	10	82	10
Non-N-fixing and Combination species	62	8	63	8

Notes: L_{SD} (p<0.05) compares between different species and between treatment groups in columns.

The G_{YIELD} of wheat from pots treated with N-fixing species (185±11 g·m^{-2}) was significantly greater than the yield from pots treated with non-N-fixing species (114±9 g·m^{-2}) and the combination treatments pots (148±9 g·m^{-2}) (Table 2). *D. sissoo*, *C. fistula* and *P. cineraria* leaves, when applied alone as well as in combination with *T. chebula*, yielded more grain than other species. Application of N-fixing leaves, resulted in average wheat yield 160% greater than control pots, and 108% greater than pots treated with a combination of non-N-fixing *T. chebula* leaves. Application of leaves of non-N-fixing species alone did not show appreciable yield increase except in the case of *S. emarginatus*.

Relationship between leaf quality and wheat productivity

Variations in wheat T_{NP} and its components (A_{NP}, B_{NP} and G_{YIELD}grain yield) were significantly positively correlated (r=0.72 to 0.79) with nitrogen concentrations of leaves (Table 3). The effect of nitrogen concentration accounted for only 52%–62% of variability (indicated by r^2) of various productivity components. Nitrogen ratios (C/N, L_{IG}/N, P_{PL}/N) showed comparable levels of correlation with productivity parameters. The ratio $L_{IG}+P_{PL}/N$, however, exhibited distinctly greater r values (0.80–0.89)

Table 3. Bivariate correlation and regression analysis (n=45) showing relationships between wheat productivity components (g·m^{-2}) and chemical quality of tree leaves. All r values are significant at p <0.001. The abbreviations are as in Table 1 and 2.

Leaf quality (x)	A_{NP} (y)	B_{NP} (y)	T_{NP} (y)	G_{YIELD} (y)
N	y=-43+348x	y=17+75x	y=-26+423x	y=-48+96x
	(r=0.77)	(r=0.72)	(r=0.77)	(r=0.79)
C/N	y=1328-28.6x	y=326-6.8x	y=1654-35.5x	y=333-8.0x
	(r=0.78)	(r=0.80)	(r=0.79)	(r=0.82)
L_{IG}/N	y=936-36.8x	y=232-8.5x	y=1167-48.4x	y=222-10.2x
	(r=0.74)	(r=0.75)	(r=0.75)	(r=0.77)
P_{PL}/N	y=875-56.9x	y=225-15.1x	y=1099-72.1x	y=205-15.7x
	(r=0.71)	(r=0.82)	(r=0.74)	(r=0.72)
$L_{IG}+P_{PL}/N$	y=993-30.0x	y=249-7.3x	y=1242-37.3x	y=238-8.3x
	(r=0.84)	(r=0.89)	(r=0.86)	(r=0.87)

We assessed interactions of various leaf quality parameters with nitrogen concentration using multiple regression analysis (Equation 1-4). For all productivity parameters, leaf variables entered in the regressions were: nitrogen concentration, C/N, P_{PL} $/N$ and $L_{IG}+P_{PL}/N$; the variable L_{IG} $/N$ was excluded. With the inclusion of these three ratios in addition to nitrogen concentration the multiple regression equations showed stronger correlations (R= 0.89 to 0.93), explaining 79%–86% of variability of the four productivity parameters. The multiple regressions reflected distinct improvement of prediction capacity over the bivariate regressions.

A_{NP} = -721.05 + 426.31(N) + 40.29 (C/N) - 31.55 (P_{PL}/N) − 27.28 ($L_{IG}+P_{PL}/N$),(R=0.89) (1)

B_{NP} = 34.02 + 48.02 (N) + 6.13 (C/N) − 8.63 (P_{PL}/N) − 6.67 ($L_{IG}+P_{PL}/N$), (R=0.93) (2)

T_{NP} = -687.03 + 474.32 (N) + 46.42 (C/N)– 40.17(P_{PL}/N) − 33.94 ($L_{IG}+P_{PL}/N$), (R=0.90) (3)

G_{YIELD} = -112.05 + 89.76 (N) + 7.64(C/N) −6.90 (P_{PL}/N) − 6.88 ($L_{IG}+P_{PL}/N$), (R=0.89) (4)

where, A_{NP} is aboveground net productivity (g·m^{-2}); B_{NP} is belowground net productivity (g·m^{-2}); T_{NP} is total net productivity (g·m^{-2}); N is nitrogen concentration (%); G_{YIELD} is grain yield (g·m^{-2}); C/N, P_{PL}/N and $L_{IG}+P_{PL}/N$ are ratios as shown in Table 1.

Discussion

Palm et al. (1997) reported that plant materials with concentrations of N >1.7%, LIG <15%, PPL <3% and C/N ratio <20 generally mineralize rapidly in soil, while those exceeding these limits initially immobilize N. While rapidly mineralizing species are high quality resources, the slow mineralisers are low quality resources. The leaves of multipurpose tree species studied here were categorized as high quality, N-fixing species and low quality, non-N-fixing species. The resource quality of soil amendments significantly affects nutrient availability (especially of N) by regulating mineralization rate.

Nyberg et al. (2002) showed very rapid and high mineralization from high quality residues of *Sesbania sesban* compared to slower and lower rates from low quality residues of *Gravillea robusta*. The use of leguminous trees has been advocated for soil improvement in improved fallows and also in biomass transfer technologies where green leaf manure is applied to the soil as fertilizer (Chirwa et al. 2003). While several studies report the effect of addition of multipurpose tree material on crop yield, its effect on total biological productivity in tropical agroecosystems has been scarcely studied. Substantially greater crop productivity and grain yield obtained by incorporation of N-fixing tree leaves (especially those of *D. sissoo*, *C. fistula* and *P. cineraria*) in this study may be due to better temporal synchronization between wheat N demand and soil N supply rate due to rapid mineralization. In contrast, low quality non-N–fixing tree leaves, especially those of *E. globulus*, *T. chebula* and *M. indica*, did not significantly affect crop productivity or grain yield, possibly due to lower soil N availability. However, when combined with leaves of N-fixing species the resultant mixture marginally increased wheat productivity, reflecting the beneficial effects of the N-fixing partner. Vinther et al. (2004) reported significantly higher yield, aboveground biomass and nitrogen uptake during the growing season from high-input than from low-input rotation. Fast decomposing leaf-material of *Leucaena leucocephala* and *Gliricidia sepium* (both nitrogen fixing legumes rich in nitrogen) were found to promote growth and yield of maize ca. 200% and 100%, respectively (Kamara et al. 2000). In contrast, in this study the addition of leaves of N-fixing species resulted in 112% and 160% increases, respectively, in productivity (T_{NP}) and yield of wheat.

N concentration and C/N ratio have been traditionally used to assess decomposition and nutrient release potential of organic inputs to agroecosystems. Use of lignin and polyphenol contents and their ratios (L_{IG}/N, P_{PL}/N, $L_{IG}+P_{PL}/N$ ratio) for the same purpose has been less frequent. It is recognized that N release from decomposing leaf materials is strongly affected by their initial N, L_{IG} and P_{PL} contents. N release from leaf material is highly reduced at high L_{IG} concentrations, which is known to be a recalcitrant substance, being greatly resistant to microbial decomposition. P_{PL} are known as disinfectants and act as bactericides (Tian et al. 1992); therefore, higher P_{PL} content in leaves can slow the decomposition of leaves by lowering the activity of microorganisms and enzymes. Interacting effects on wheat productivity of L_{IG} and P_{PL} contents with positively related nitrogen concentration of leaves is evident from multivariate analysis of our data. While conforming with current opinion on the significance of N, L_{IG} and P_{PL} contents of tree leaf applications, our findings show stronger relationships between the $L_{IG}+P_{PL}/N$ ratio of incorporated tree leaves and wheat productivity and grain yield. The routinely determined L_{IG+} P_{PL}/N ratio can be employed as an index for evaluating the potential of different tree leaves for enhancing cereal crop productivity and yield.

Conclusions

The incorporation of finely cut leaves of N-fixing multipurpose trees (*D. sissoo*, *C fistula* and *P. cineraria*) significantly enhances the biological productivity of wheat, at least in the short term, in dry tropics. Interactions amongst N concentration (main nutrient) and L_{IG} and P_{PL} contents affect T_{NP} and G_{YIELD} of wheat. Low quality tree leaves (e.g. *E. globulus*, *T. chebula* and *M. indica*) yielded marginal increases in wheat productivity when mixed with high quality leaves. Among several chemical quality parameters of leaves, the $L_{IG}+P_{PL}/N$ ratio appeared to be the most reliable index for mass screening of multipurpose tree species for assessing their potential impacts on crop productivity and yield. Leaves of more tree species should be assessed for their potential utility as soil amendments for key cereal crops (such as wheat, rice, maize) in Indian dry tropics where such practice is uncommon.

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References

Akkaya A, Dokuyucu T, Kara R, Dunilupinar Z. 2006. The effect of walnut and pine leaves on bread wheat growth and frequencies of common weed species in the East-Mediterranean region. *Journal of Environmental Biology*, **27**(3): 523−527.

Anderson JM, Ingram JSI. 1993. *Tropical Soil Biology and Fertility: A Handbook of Methods.* Wallingford (UK): CAB International Publication, Oxford University Press, p. 221.

Anthofer J, Hanson J, Jutzi SC. 1998. Wheat growth as influenced by application of agroforestry tree prunings in Ethiopian highlands. *Agroforestry Systems*, **40:** 1−18.

Byard R, Lewis KC, Montagini F. 1996. Leaf litter decomposition and mulch performance from mixed and monospecific plantations of native tree species in Costa Rica. *Agriculture Ecosystems and Environment*, **58**: 145−155.

Chirwa PW, Black CR, Ong CK, Maghembe JA. 2003. Tree and crop productivity in gliricidia/maize/pigeonpea cropping system in Southern Malawi. *Agroforestry Systems*, **59**: 265−277.

Costantinides M, Fownes JH. 1994. Nitrogen mineralization from leaves and litter of tropical plants: Relationship to nitrogen, lignin and soluble polyphenol concentrations. *Soil Biology and Biochemistry*, **26**: 49−55.

Effland MJ. 1977. Modified procedure to determine acid insoluble lignin in wood and pulp. *Technical Association of Pulp Industry (TAPPI)*, **60**: 143−144.

Handayanto E, Cadisch G, Giller KE. 1994. Nitrogen release from prunings of legume hedgerow trees in relation to quality of the prunings and incubation method. *Plant and Soil*, **160**: 237−248.

Haynes RJ. 1986. The decomposition process: mineralization, immobilization, humus formation, and degradation. *In*: R.J. Haynes (ed.), *Mineral nitrogen in the plant-soil system*. Orlando, Fl : Academic Press, pp. 52−109.

Jackson ML. 1973. *Soil Chemical Analysis*. Englewood, Cliffs (New Jersey): Prentice-Hall Inc Publisher. p. 498.

Kamara AY, Akobundu I.O, Sanginga N. Jutzi SC. 2000. Effect of mulch from selected multipurpose trees (MPTs) on growth, nitrogen nutrition and yield of maize (*Zea mays* L.). *Journal of Agronomy and Crop Science*, **184**: 73−80.

Kundu S, Battacharya R, Prakesh V, Gupta HS, Pathak H, Ladha JK. 2007. Long-term yield trend and sustainability of rainfed soybean-wheat system through farmyard manure application in the sandy loam soil of Indian Himalayan. *Biology and Fertility of Soils*, **43**: 271−280.

Lehman J, Sehroth G, Zech W. 1995. Decomposition and nutrient release from leaves, twigs and roots of three alley-cropped tree legumes in central Tago. *Agroforestry Systems*, **29**(1): 21−36.

Mafongoya PL, Nair PKR, Dzowela BH. 1996. Multipurpose tree pruning as a source of nitrogen to maize under semi-arid conditions in Zimbabwe 3, Interactions of pruning quality and time and method of application on nitrogen recovery by maize in two soil types. *Agroforestry Systems*, **35**: 57−70.

Myers RJK, Palm CA, Cuevas E, Gunatilleke IUN, Brossard M. 1994. The synchronization of nutrient mineralization and plant nutrient demand. *In*: P.L. Woomer and M.J. Swift (eds.), *The biological management of tropical soil fertility*. UK: Wiley-Sayce Publication, Oxford University Press, pp. 1−116.

McBrayer JF, Cromack K.Jr 1980. Effect of snow-pack on oak-litter breakdown and nutrient release in a Minnesota forest. *Pedobiologia*, **20**: 47−54.

Mwiinga RD, Kwesiga FR, Kamara CS. 1994. Decomposition of leaves of six multipurpose tree species in Chipata, Zambia. *Forest Ecology and Management,* **64** (2-3): 209−206.

Nyberg G, Ekblad A, Buresh R, Högberg P. 2002. Short-term patterns of carbon and nitrogen mineralization in a fallow field amended with green manures from agroforestry trees. *Biology and Fertility of Soils*, **36**: 18−25.

Palm CA, Mayers RJK, Nandwa SM. 1997. Combined use of Organic and Inorganic nutrient Sources for Soil Fertility Maintenance and Replenishment. *In*: R.J. Buresh, P.A. Sanchez and F. Cathoun (eds), *Replenishing soil fertility in Africa*. SSSA special publication no. 51. Madison, Wis: Soil Science Society of America, American Society of Agronomy, pp. 193−217.

Sarrantonio M. 2003. Soil response to surface-applied residues of varying carbon-nitrogen ratios. *Biology and Fertility of Soils*, **37**: 175−183.

Semwal RL, Maikhuri RK, Rao KS, Sen KK, Sexena KG. 2003. Leaf litter decomposition and nutrient release patterns of six multipurpose tree species of central Himalaya, India. *Biomass and Bioenergy*, **24**: 3−11.

Silva GTA, Matos LV, Nobrega PO, Campello EFC, Resende AS. 2008. Chemical composition and decomposition rate of plants used as green manure. *Scientia Agricola*, **65**(3): 298−305.

Srivastava R, Singh KP. 2002. Variations in soil organic C and N storage due to cultivation practices in the Gangetic plain, India. *International Journal of Ecology and Environmental Sciences*, **28**: 193−199.

Tian G, Kang BT, Brusaard L. 1993. Mulching effects of plant residues with chemically contrasting compositions on maize growth and nutrient accumulation. *Plant and Soil*, **153**: 179−187.

Tian G, Kang BT, Brussaard L. 1992. Effects of chemical composition of N, Ca, and Mg release during incubation of leaves from selected agroforestry and fallow plant species. *Biogeochemistry*, **16**: 103−119.

Vinther FP, Hansen EM, Olesen JE. 2004. Effects of plant residues on crop performance, N mineralization and microbial activity including field CO_2 and N_2O fluxes in unfertilized crop rotations. *Nutrient Cycling in Agroecosystems*, **70**: 189−199.